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Our work explored a variety of research areas, all directed towards obtaining an understanding of visual cortical funciton using psychophysical techniques. In particular, we examined visual search, visual attention, the encoding of occluding surfaces, and color filling-in. With respect to visual search, we found a new unexpected relation between distractor number and reaction time, showing that for particular tasks, performance improved when distractor number increased. With respect to visual attention we obtained new information to support the specific hypothesis which proposed that express saccades were due to a rapid disengagement of attention from the fixation. With respect to occluded surfaces, we provided a new theoretical framework to understand the large number of new results collected, suggesting the generic view principle. Finally, with respect to color filling-in, we found evidence that such a hypothetical process can be interrupted after the presentation of a stimulus and we evaluated its spatio-temporal time course.

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Research objectives

Our goal was to examine a number of areas which we felt could ultimately be related to visual cortical function:

With respect to visual attention, our view was that the more rigorous methods of psychophysics might be very helpful, both to confirm earlier work obtained with other methods and also to provide a link to a large database of facts and concepts emerging from visual psychophysical studies. (with Dr. Manfred Mackeben).

With respect to visual search, we were interested in examining the implications of a number of current theories of attentional control. (with Dr. Mary Bravo).

With respect to surface representation, our goal was more exploratory; to see the degree to which an understanding of occlusion could be advanced, particularly using new computer graphics techniques that were then being introduced to the laboratory. (with Dr. Shinsuke Shimojo).

With respect to color filling-in, we wanted to see whether such filling, postulated in certain abnormal situations (such as in the cases of scotomata or stabilized vision) could be demonstrated using more conventional psychophysical techniques. (with Dr. Michael Paradiso).

Status of research

Work during this period proved to be more rewarding than anticipated and we were almost overwhelmed by the wealth of surprising new findings particularly in the area of surface representation. These findings in turn have prompted an intense interest in developing a more theoretical understanding of this topic.

Significant accomplishments

Over the current grant proposal, considerable progress has been made in a variety of project areas. The main bulk of work on surface representation has been done in collaboration with Shinsuke Shimojo. Our joint work deals with three related areas, all concerned with the multiple representation of surfaces.

First we addressed the issue of boundedness of surfaces and the termination of lines. We asserted that a bounded surface in an image could be either surrounded by an intrinsic border (reflecting the outline of the surface itself) or it could be bounded as a result of occlusion.

Second, we have explored the problem of occlusion in relation to binocular vision. Capitalizing on the fact that there is a very specific pattern of unpaired monocular points in the binocular image, we have outlined and systematized a number of important phenomenon which we label under the rubric of DaVinci stereopsis. In this work, we show that instead of seeing binocular rivalry when viewing these unmatched points, our visual system is remarkably adaptive, providing us with reliable depth from such points. Even more surprising is the fact that the presence of such unpaired points can give rise to the formation of subjective occluding contours and subjective occluding surfaces. In all our experimental work, we find that perception is critically dependent on which eye receives the unpaired points.

Third, we have explored and are continuing to explore the curious emergence of perceived transparency in a number of simple untextured stereograms. We outlined the conditions under which perceived transparency is triggered as well as showing that when it is triggered, seemingly more primitive features can be drastically altered. Thus when perceived transparency is triggered, we see color spreading into otherwise uncolored areas, subjective contours appearing in some sections of the image and removed in others, depth of regions is radically altered, and object shapes are dramatically changed because of the reversal of figure and ground. We hypothesize that there are 3 critical variables important in the perception of transparency. These are depth, luminance and the presence of collinearly.

Work in the area of visual attention and visual search has been done in two separate collaborative efforts, one with Manfred Mackeben, the other with Mary Bravo. Each is described in turn. With Dr. Mackeben we completed a study on "express attentional" shifts. Our goal was to test Burkart Fischer's hypothesis that express saccades are caused by a rapid deployment of attention to the target site (Fischer, 1987). Using the "gap" paradigm which favors the appearance of express saccades, we predicted and found that the attentional shift to a peripheral target was much more rapid for gap times comparable to those which elicit express saccades. As such, our study provided important missing data to link attention to saccadic eye movements.

In visual search experiments, conducted largely in collaboration with Dr. Mary Bravo, our starting point was to think about the allocation of focal attention in visual search displays. Seriously considering various theories of attentional guidance (Koch and Ullman, 1985; Treisman, 1985; Julesz, 1985), we made a somewhat counterintuitive set of predictions. Under some circumstances, we predicted that reaction times should decrease with increasing numbers of distractors in a visual search task, rather than increase as has generally been the case. Our approach was to use tasks where attentional focussing to the target was required, asking the observer to make a speeded forced-choice discrimination of a non-cue feature of the target. Because this feature was also present in the distractors, it required that the observer focus attention on the target. For most of the experiments, we used colored cues and had the observer make a discrimination as to the shape of the odd colored target. As predicted from a consideration of "top down" vs "bottom up" theories, only in the mixed case did reaction times decrease with increasing numbers of distractors. In addition, when using the more usual present-vs-absent task employed by others, the reaction time vs distractor number function was also flat, as expected.

In collaboration with Dr. Michael Paradiso, a post-doctoral fellow in my lab in San Francisco, we have completed both empirical and theoretic studies of color filling-in. Our first goal was to see whether filling-in, hypothesized to occur in stabilized vision and in patients with retinal lesions, might also be seen in normal everyday vision. Our stimulus was a homogeneous disk, presented briefly. When viewed in isolation, it appeared as just that, a homogeneous disk. However, when it was followed by various patterns, either in the same or the other eye, a dramatical reduction in brightness in the center of the disk could be seen. Our original working hypothesis was that a hypothetical color-filling process had been interrupted. By varying the distance of a circular pattern following the disk and its onset relative to the disk, we were able to characterize the process as one of spatial propagation with a relatively high velocity.

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